An Innovative Approach for Fostering Computer-Supported Collaboration

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Abstract: Computer-supported collaboration is still problematic with regard to the interaction between spatially distributed group members. In this paper, an innovative approach to tackling this problem is presented. This approach is based on fostering "knowledge and information awareness" that is defined as awareness of a group member with regard to task-relevant knowledge and information underlying this knowledge of his/her collaborators. An experimental study described in this paper confirmed the efficiency of knowledge and information awareness on computer-supported collaborative problem solving.

Knowledge and Information Awareness to Tackle Problems in CSC

Computer-supported collaborative learning (CSCL), defined as "practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts" (Koschmann, 2003, p. 18), is becoming increasingly important. In the context of CSCL, not only are learning settings in focus, but also settings that are learning-relevant, like *computer-supported collaborative problem solving* which is addressed in this paper. Results of empirical research confirm the potential of computer-supported collaboration (CSC): For example, it has been shown that learners in such settings may make higher quality decisions and may be better in idea generation (Fjermestad, 2004). However, research results also show that efficient CSC is not easy to achieve: For example, according to Janssen, Erkens, Jaspers, and Broeken (2005), groups in CSC settings often have communication and interaction problems. In the CSCL research community, there are different strands of research addressing such problems of CSC, e.g., approaches that aim at enhancing different kinds of group awareness. Following Gross, Stary, and Totter (2005) group awareness is defined as "consciousness and information of various aspects of the group and its members" (p. 327). However, in the literature, there is no consensus about how this term is defined. Mostly, the meaning of awareness refers to social or action awareness (e.g., Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003). However, in knowledge-rich and information-rich situations, these awareness types may not be enough to support effective CSC, but "*knowledge and information awareness*" (KIA) is needed, which is defined as awareness of a group member regarding both the knowledge and the information underlying this knowledge of his/her collaborators (Keller, Tergan, & Coffey, 2006). KIA can be fostered by means of using advanced digital concept maps that have not only the potential to represent conceptual *knowledge* (i.e., concepts and their relations), but also *information* underlying a concept (e.g., an image or an explanation of a concept). It is suggested that being aware of the knowledge of others and the information underlying this knowledge, may help cooperative problem solvers in shared knowledge-construction and problem-solving tasks. This assumption is based on the *theory of transactive memory* (Wegner, 1986). According to this theory a transactive memory system is a set of individual memory systems combined with the communication between the group members. In the present project, KIA is supported by means of an environment visualizing knowledge and information visualizations of the collaborators by means of digital concept maps. It is assumed that KIA is helpful in a computer-supported collaborative problem-solving scenario, because it could be expected that KIA has a positive impact on interaction, especially on communication and coordination and, therefore, also on collaborative problem solving: Following Clark and Brennan (1993), shared understanding in communication is crucial for individuals working in a group. Making visual representations of the knowledge structures and the underlying information of each group member available to the group should facilitate shared understanding and, thus, communication. Moreover, it has been shown that information that is shared by all group members is often mentioned in group discussion, while unshared information that is known by only some group members, mostly remains unmentioned (e.g., Stasser, Vaughan, & Stewart, 2000). However, such unshared information could be important for problem solving. Therefore, it is important to also recognize unshared information. By comparing the external knowledge and information representations of the collaborators, group members can easily recognize which knowledge and information is shared and which is not. This should have a positive effect on group coordination. In addition, it is assumed that the possibility to view the knowledge and underlying information of other group members provides a kind of affordance for each individual to make use of these representations (Suthers, 2005).

Experimental Study

The experiment investigated whether groups using an environment for fostering KIA collaborate more efficiently in problem solving tasks than groups that do not have a KIA environment.

Method

Participants: Participants were 90 students (58 female, 32 male) of the University of Tuebingen, Germany. Average age was 24.47 (SD = 3.83). The students were randomly assigned to the experimental condition (N = 15 groups) or to the control condition (N = 15 groups).

Materials and Procedure: The participants worked in groups of three students sitting in separate room sections. They could not see each other, but could speak with each other. The domain was about caring for a fictitious kind of spruce forest and consisted of several concepts, relations, and information elements underlying the concepts. These elements were evenly distributed among the three group members. At the start of the study, *control variables* (e.g., computer experience) were measured by a questionnaire. Afterwards, the participants had to *practice the use of CmapTools* (http://cmap.ihmc.us/). At the outset of the *individual phase 1* (23 minutes), the group members worked separately, accessing the information elements in their own information window on the left side of their desktop and structuring their information and knowledge in form of concept maps in their own working window on the right side of their desktop. In the *individual phase 2* (5 minutes), each participant of the control group examined his/her own map. Each participant of the experimental group, however, could also see the maps of his/her collaborators. After this activity, there was a *manipulation check* to measure the amount of KIA acquired (15 items). In the *collaboration phase* (40 minutes), the group members collaborated on solving two problems, i.e., which pesticide and which fertilizer they would use. To solve these problems, the participants needed to compile their knowledge and information. To do this, they used a shared working window to create a common digital concept map. During this phase, they could speak with each other. In the control condition, the participants could only see their own working window and the shared working window. In the experimental condition, the participants also saw the individual maps of their collaborators to become aware of the knowledge and information their collaborators had. Finally, a *knowledge test* was used to measure the knowledge the participants had acquired and a *questionnaire* was used to assess, e.g., difficulties regarding collaboration.

Design and Dependent Measures: The analysis was based on a comparison of the *experimental condition*, in which the groups were provided with an environment for fostering KIA, and the *control condition*, in which the groups worked without it. The dependent measures were the *domain knowledge* (30 multiple-choice items)*, the quality of the common concept map* created in the collaboration phase, the *quality of the group answers to the two problem-solving tasks,* and *process-related measures.*

Results and Discussion

In all analyses of variance reported here, the control variable “experience in creating computer-based graphics” was used as a covariate, because of a significant difference between the control and the experimental condition. All analyses presented here are based on group level, i.e., the group values are calculated as means of the values of the individuals of a group. This was necessary, due to the fact that the members of a group are not independent of each other. *The first series of analyses* confirmed that the groups in the experimental condition acquired KIA by using the KIA environment: The analysis of the *manipulation check* after the individual phase showed that the experimental groups achieved on average 58.75% of the score in tasks asking for information that only one of the other group members had and 59.44% of the score in tasks that asked for information that only the two other collaborators had. The analysis of the questionnaire items (rating scales: 1 = “no agreement” and 5 = “complete agreement”) showed, e.g., that the experimental groups agreed on average that it was helpful to have access to the maps of the collaborators ($M_E = 4.27$; $SD_E = 0.75$).

The second series of analyses explored the impact of the use of the KIA environment on the dependent measures. The questionnaire measuring *process-related aspects* showed that participating in the study was more stressful in the control groups ($M_C = 3.2$; $M_E = 2.7$; $F(1,27) = 4.66$; $MSE = 0.28$; $p < .05$), although the experimental groups had more problems regarding the use of the different windows on the desktop ($M_C = 1.8$; $M_E = 2.2$; $F(1,27) = 6.25$; $MSE = 0.25$; $p < .05$) compared to the control groups. The analyses of the *log files* with regard to uptake events, i.e., events in which group members take up and build on prior contributions (Suthers, 2006), confirmed that there were significantly more intersubjective uptake events in the experimental groups than in the control groups ($M_C = 0.5$; $M_E = 3.3$; $F(1,27) = 18.20$; $MSE = 2.93$; $p < .001$). KIA seems to foster intersubjective knowledge construction. The analysis of the *knowledge test* revealed, e.g., better performance for the experimental groups regarding the *knowledge on domain relations* that were shared by a participant collaborator dyad compared to the control groups ($M_C = 2.1$; $M_E = 2.4$; $F(1,27) = 4.2$; $MSE = 0.14$; $p < .05$). Moreover, the analyses revealed that the experimental groups gained higher values in *knowledge regarding information underlying a concept* that is only shared by the other collaborators ($M_C = 2.6$; $M_E = 2.9$; $F(1,27) = 4.17$; $MSE = 0.41$; $p = .05$). These results provide evidence of the efficiency of the KIA environment. Regarding the *quality of the group maps*, there were no differences between the conditions regarding the number of correct relations and concepts (nodes: $M_C = 12.9$; $M_E = 12.6$; $F(1,27) = 1.71$; $MSE = 0.46$; $p = .20$; relations:

$M_C = 23.3$; $M_E = 21.5$; $F(1,27) = 1.81$; $MSE = 22.21$; $p = .19$). However, it seems that the experimental groups tried to avoid information overload in their maps: There were more intersections of relations in the group maps of the control groups than in the maps of the experimental groups ($M_C = 15.3$; $M_E = 9.0$; $F(1,27) = 4.84$; $MSE = 51.88$; $p < .05$). With regard to the *problem-solving tasks*, the experimental groups tended to be more confident that they had solved the two tasks correctly (pesticide problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.38$; $MSE = 0.47$; $p = .077$; fertilizer problem: $M_C = 3.8$; $M_E = 4.2$; $F(1,27) = 3.17$; $MSE = 0.57$; $p = .086$). This subjective estimation of the participants was partly mirrored in objective results, namely in the group answers given: Regarding the number of correct answers to the pesticide problem, the data did not show a significant difference between the conditions (Pearson-$\chi2$ (2) = 3.20; $p = .20$). However, regarding the number of correct answers to the fertilizer problem, the experimental groups attained a marginally higher performance compared to the control groups (Pearson-$\chi2$ (2) = 4.9; $p < .087$).

Summary

The presented study demonstrated that computer-supported collaborative problem solving can be supported by enhancing KIA. In this study, an experimental condition using an environment for enhancing KIA was compared to a control condition that ran without it. The analyses showed that the experimental groups acquired a substantial amount of KIA by using the KIA environment. Results further indicate that participating in the study was more stressful for the control groups, although the experimental groups had more difficulties in using the windows. Therefore, the benefit of using a KIA environment seems to be great enough to compensate for the higher cognitive load caused by the need to use more windows on the screen. By analyzing the log files, it could be confirmed that, in the experimental groups, more intersubjective meaning construction took place than in the control groups. Moreover, the analyses showed that the experimental groups achieved higher performance in both knowledge regarding content information that was only shared by the other collaborators and knowledge regarding relation information that an individual and another collaborator had. Regarding the quality of the group maps, there was no difference in the quality in the sense of correct nodes and relations between the conditions. However, the analyses showed that the experimental groups tried to avoid information overload in their map. Most importantly, the study demonstrated that using a KIA environment was helpful for problem-solving performances.

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